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# PATENT SPECIFICATION

1,164,307

DRAWINGS ATTACHED.

Date of Application (No. 52085/66) and filing Complete Specification: 21 Nov., 1966.

Application made in United States of America (No. 515,401) on 21 Dec., 1965.

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1,164,307



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## COMPLETE SPECIFICATION.

### Magnets.

We, GENERAL ELECTRIC COMPANY, a corporation organized and existing under the laws of the State of New York, United States of America, of 1 River Road, Schenectady 5, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to permanent magnets and to permanent magnet assemblies for use in loudspeakers and to a process and apparatus for the production of permanent magnets.

Permanent magnets ordinarily used in permanent magnet loudspeakers are anisotropic, i.e., they have a desired direction of magnetization. This is accomplished by subjecting the magnetisable material during cooling in the magnetic hardening process, to a magnetic field coinciding with the desired direction of magnetization.

Typical permanent magnet loudspeakers contain a permanent magnet, a pole piece and one or more return path elements, all arranged in magnetic circuit relationship. The magnetic flux in such circuits flows axially through the magnet, turns 90°, and flows radially across an air gap to interact with a voice coil. Thus the path of the magnetic circuit is generally rectangular. To enhance the performance of such loudspeakers, the magnets have a desired direction of magnetization which runs axially through the magnet to coincide with the path of the magnetic circuit. The structure of permanent magnet assemblies in loudspeakers is, to a large extent, dependent upon and determined by the path of the magnetic circuit in such permanent magnet assemblies, which in turn is closely inter-

related with the desired direction of magnetization of the loudspeaker magnet.

Briefly, this invention provides a permanent magnet having a principal or desired direction of magnetization lying along an axially disposed arcuate path, the ends of which intersect the side surface of the magnet. In effect, the magnetic flux flows out the sides of the permanent magnet rather than the ends. Such a magnet when used in a loudspeaker can result in higher efficiency because the flux is concentrated where it should be—in the air gap. A second result of such use is that the magnetic circuit in a loudspeaker comprising the permanent magnet and the return path elements is considerably simplified. No bottom return path element or top pole piece is necessary and it is possible, as set out more fully below with reference to a preferred embodiment of the invention, to simplify and make more compact even those elements of the return path which remain.

The invention will be more clearly understood from the following description of a preferred embodiment thereof taken in connection with the accompanying drawing in which:

Figure 1 is an elevational sectional view of a cylindrical loudspeaker magnet in accordance with this invention showing the desired direction of magnetisation;

Figure 2 is a sectional view of a permanent magnet assembly in accordance with this invention comprising a return path element and the permanent magnet of Figure 1;

Figure 3 is a sectional view of a loudspeaker embodying the permanent magnet assembly of Figure 2; and

Figure 4 is a sectional view of apparatus suitable for forming permanent magnets in accordance with the invention.

As can be seen in Fig. 1, a cylindrical loudspeaker magnet 1 having end surfaces 2 and 3 at opposite axial extremities and a side surface 4 is magnetised so that its desired direction of magnetization is along a curved or arcuate path 5 disposed symmetrically around the central axis A—A of the permanent magnet. It will be noted from Fig. 1 that the curved path 5 intersects the side surface 4 of the magnet at 6 along the top portion of the magnet and at 7 along the bottom portion of the magnet. Thus, a first pole will be created along one extremity of a side surface of the magnet at 6 and a second pole will be created on the opposite extremity of the side surface of the magnet at 7. The path of desired magnetization shown in section in Fig. 1 extends symmetrically completely about the axis of the permanent magnet. The path of magnetisation is therefore described by rotating curve 5 through a complete 360° arc about the central axis A—A of the magnet. Any plane passing through the central axis of the magnet would produce the magnetisation path shown in section in Fig. 1.

The utilization of a permanent magnet in a loudspeaker magnet circuit, magnetised as shown in Fig. 1, is shown in Fig. 2. As there illustrated, all that is necessary to complete the magnetic circuit is an open cylindrically shaped return path element 8. The permanent magnet fits within and is coaxial with return path element 8. A flange 9 on the inner surface of return path element 8 contacts the permanent magnet 1 along its lower extremity 7. The opposite extremity 6 of the side surface of the permanent magnet is spaced from return path element 8 to form the air gap 10.

The permanent magnet-return path structure shown in Fig. 2 permits a number of significant advantages in the construction of permanent magnet loudspeakers. Measurements indicate that 90% of the total magnetomotive force is made available at air gap 10 as opposed to 65% to 75% in conventional magnet structures. Additionally, virtually 100% of the total magnetic flux may be made to enter the general region of the voice coil versus a loss of as much as 20% of such flux to regions outside the voice coil region in conventional magnet structures. In substance, use of a magnet magnetised as illustrated in Fig. 1, with the return path assembly illustrated in Fig. 2, makes possible the utilization in loudspeaker structures of a much higher percentage of the energy of conventional permanent magnets.

The invention also makes possible the utilization of return path elements of thin-gauge metal. This is possible because the greater efficiency of the magnetic circuit permits the use of lower flux densities to

achieve an equivalent air gap density and thus equivalent loudspeaker performance. A conventional return path or yoke structure in a loudspeaker must have sufficient cross-sectional area so that the flux density does not exceed the saturation point of the metal. Because the flux density per unit area of return path is smaller in the loudspeaker assembly in accordance with this invention, less cross-sectional area in the return path element is necessary. This enables efficient loudspeaker magnet assemblies to be built utilizing thin-gauge, soft-steel return paths. An additional reason why the return path elements need be of less cross-sectional area is based upon the fact that the magnetic flux is distributed over a wider area at the point of contact with the return path element.

The foregoing is illustrated more clearly in the loudspeaker shown in Fig. 3 of the drawing. Speaker basket 11 has depended from its central portion a tubular return path element 12 integral with and formed from the speaker basket. It is possible to use metal from the speaker basket, previously discarded in the stamping of such baskets, to make the return path elements of the speaker both because of the simplified design of the return path and because of the ability to use lighter gauge metal. This aspect of the invention is more fully disclosed in the copending Application No. 52084/66 (Serial No. 1,164,306). The remaining components of the loudspeaker are a frusto-conical diaphragm 13 and a flexible spider 14. A voice coil 15 is wound on a voice coil former 16 and is coupled to diaphragm 13.

Another advantage of the permanent magnet in accordance with this invention is also illustrated by Fig. 2. The width of the air gap 10 is the same as the width of the throat 17 formed between the remainder of the return path element and the lateral sides of the permanent magnet. While this structure is not unknown in the loudspeaker art, it has almost always been avoided because greatest efficiency in loudspeaker structures is obtained by maintaining a large degree of separation between the axial flow of magnetic flux in the magnet and the return axial flow in the lateral portion of the return path. This discourages radiation of flux from the sides of the magnet to the return path element at areas other than the air gap. In conventional loudspeaker assemblies the flux flows in an axial direction through the permanent magnet—any radial flow of flux other than at the extremities of the magnet must be discouraged. In the loudspeaker magnet assembly construction shown in Fig. 2, there is already a radial component (toward the sides of the magnet) in the flow of flux in the magnet 1 so that radial flow is

not discouraged except for a very small area at the axial center of the magnet. It is thus possible to reduce considerably the dimensions of the throat area of the permanent magnet return path system and in turn to miniaturize the construction of the loudspeaker. While the assembly does not require in all cases that the air gap and throat width be the same dimension (as in Figs. 2 and 3), permanent magnets in accordance with the invention nevertheless do make it possible for the throat section to be narrower than in conventional loudspeaker structures.

The present invention also encompasses a unique method for providing magnets having a desired direction of magnetisation as set forth in connection with the description of Fig. 1 above. An apparatus suitable for providing such permanent magnets is shown in Fig. 4. Such apparatus includes a removable ceramic tube 19 for insertion therein of bodies of material 20, 21, 22 and 23 for forming permanent magnets. Soft iron washers 24, 25, 26 and 27 at the juncture of each two bodies act as pole pieces. An outer cylindrical tube 28 of any magnetically permeable material, such as soft iron, surrounds the entire structure and acts as a return path element. The outer tube 28 is wound in periodic fashion by windings 29, 30, 31 and 32 to create a series of poles of opposite polarity at the extremities of the bodies of material. Thus, it is wound in a first direction around body 20, an opposite direction around body 21, the first direction around body 22, and so forth, to create alternating north and south poles surrounding abutting end portions of the bodies. As can be seen in Fig. 4, this arrangement permits magnetic flux to flow from washers 24, 25, 26 and 27 through an arcuate or curved path in each of the cylindrical bodies of material to an opposite pole at the next successive washer, through the return path element to repeat the circuit. This circuit is illustrated in the drawings for forming three magnets but would of course be repeated throughout the apparatus.

By arranging any number of such periodic fields around a thermally insulating, temperature-resistant tube such as tube 19 containing the bodies of material for forming loudspeaker magnets, a number of such speaker magnets may be formed having a desired direction of magnetisation. The bodies of material are first heated to a temperature above their Curie temperature, and preferably 300°C. above their Curie temperature, and then cooled through the Curie temperature to room temperature in accordance with a prescribed cooling cycle, while the bodies are subjected to a magnetic field in the foregoing apparatus. The cooled magnet will have a desired direction of mag-

netisation along the curved path described above.

A specific example of a process in accordance with this invention is as follows:

Ceramic tube 19 (Fig. 4) is loaded with a plurality (as, for example, a hundred) sand-cast cylindrical alnico 5 bodies ground to proper dimensions and having the following composition in percentages by weight: 8 aluminum, 14 nickel, 24 cobalt, 3 copper, balance iron. The tube is placed in an induction heater and the tube and bodies are heated to 1100°C. The Curie temperature of the alnico 5 composition is 800–850°C. The tube and bodies are then removed from the induction heater and inserted through the washers so that the line of contact between two adjacent bodies falls centrally within one of the washers 24, 25, 26 and 27. The bodies are then allowed to remain in the orientation field while the periodically arranged windings are energized until the bodies have cooled through their Curie temperature to 600–700°C., which ordinarily takes about five to ten minutes at ambient temperatures.

The permanent magnets to which the invention is particularly directed are those produced from iron-cobalt-nickel-aluminum alloys commonly known as alnico 5 but other permanent magnetic materials may be used.

#### WHAT WE CLAIM IS:—

1. An anisotropic permanent magnet having end surfaces and therebetween a circumferential side surface, the magnet having a desired direction of magnetisation along an arcuate path extending from a first position on said side surface adjacent one of said ends into the body of the magnet intermediate its end surfaces to a second position on said side surface adjacent the other of said ends to provide first and second magnetic poles which extend around the entire circumference of said side surface at said first and second positions respectively.

2. A magnet as claimed in Claim 1, in which said magnet is cylindrical and said poles are at opposite extremities of said side surface.

3. A magnet as claimed in Claim 2, in which the arcuate path of magnetisation is symmetrical about the longitudinal axis of the cylindrical magnet.

4. A magnet as claimed in Claim 1, 2 or 3, in which said magnet includes alnico 5 magnetic material.

5. An anisotropic permanent magnet substantially as described herein with reference to Figures 1 and 2 of the accompanying drawings.

6. A permanent magnet assembly for a loudspeaker comprising a permanent magnet as claimed in any one of Claims 1 to 5

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 5 and a return path element together adapted to provide a magnetic circuit, the permanent magnet being coaxial with and positioned within the return path element, the return path element contacting one of said poles and the other of said poles being spaced from the return path element to form an air gap.

10 7. A method of magnetising a body of material to form a permanent magnet as claimed in Claim 1, comprising bringing said material to a temperature above its Curie temperature, surrounding said material with a magnetic field and applying said field to said material so that it passes in an arcuate path through the material from a first position on the circumferential side surface of the material adjacent one of the ends thereof, through the body of the material to a second position on said side surface adjacent the other of said ends while the material is cooled through its Curie temperature to form magnetic poles which extend around the entire circumference of said side surface at said first and second positions.

20 8. A method of magnetising a plurality of bodies of material to form a plurality of permanent magnets as claimed in Claim 7, including positioning said plurality of bodies of material end to end and surrounding each body of material with a magnetic field so that each body of material has applied thereto a different one of said fields to form said poles.

9. A method of magnetising a plurality of bodies of material to form a plurality of permanent magnets substantially as described herein with reference to Figure 4 of the accompanying drawings.

40 10. Apparatus for carrying out the method as claimed in Claim 8, comprising a removable inner ceramic tube for insertion therein of said bodies of material, a plurality of soft iron washers mounted on said tube and spaced apart so that the abutting ends of adjacent bodies of material inserted within the ceramic tube are surrounded by a washer, an outer cylindrical magnetically permeable tube mounted coaxially with and surrounding said inner tube having said washers mounted thereon and a plurality of windings on the inner ceramic tube each winding being positioned between a pair of washers so that on passing electric current through each winding a magnetic field is created which is applied to said bodies of material through adjacent washers, the outer tube providing a return path for the applied magnetic fields.

55 11. Apparatus for carrying out the method as claimed in Claim 8 substantially as described herein with reference to Figure 4 of the accompanying drawings.

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COMPLETE SPECIFICATION

1 SHEET

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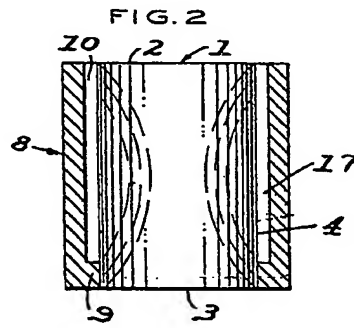
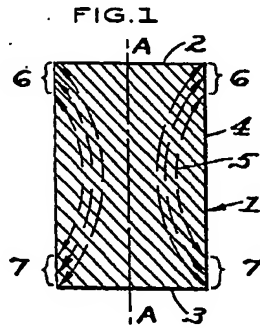


FIG.3

